Photomask and Next-Generation Lithography Mask Technology XXI

Kokoro Kato
Editor

15–17 April 2014
Yokohama, Japan

Sponsored by
PMJ Photomask Japan
BACUS
SPIE

Published by
SPIE

Volume 9256

Proceedings of SPIE 0277-786X, V. 9256

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Photomask and Next-Generation Lithography Mask Technology XXI, edited
by Kokoro Kato, Proc. of SPIE Vol. 9256, 925601 · © 2014 SPIE
CCC code: 0277-786X/14/$18 · doi: 10.1117/12.2074854

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:
Author(s), "Title of Paper," in *Photomask and Next-Generation Lithography Mask Technology XXI*, edited by Kokoro Kato, Proceedings of SPIE Vol. 9256 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X
ISBN: 9781628413236

Published by
SPIE
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Copyright © 2014, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is $18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/14/$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B … 0Z, followed by 10-1Z, 20-2Z, etc.

The CID Number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID Number.

Contents

vii *Conference Committees*

INVITED SESSION

9256 02 **Achievements and challenges of EUV mask imaging (Invited Paper)** [9256-44]
N. Davydova, E. van Setten, R. de Kruif, ASML Netherlands B.V. (Netherlands); B. Connolly, Toppan Photomasks, Inc. (Germany); N. Fukugami, Y. Kodera, H. Morimoto, Y. Sakata, J. Kotani, S. Kondo, T. Imoto, Toppan Printing Co., Ltd. (Japan); H. Rolff, A. Ullrich, Advanced Mask Technology Ctr. GmbH Co. KG (Germany); A. Lammers, G. Schiffelers, J. van Dijk, ASML Netherlands B.V. (Netherlands)

INSPECTION AND CLEANING

9256 03 **Accurate mask model for advanced nodes** [9256-27]
N. Zine El Abidine, F. Sundermann, E. Yesilada, STMicroelectronics (France); E. H. O. Ndiaye, Mentor Graphics Corp. (France); K. Mishra, S. Paninjath, Adarsh Eco Space (India); I. Bork, P. Buck, Mentor Graphics Corp. (United States); O. Toublan, Mentor Graphics Corp. (France); I. Schanen, LAHC, Institut de Microélectronique, Electromagnétisme et Photonique (France)

9256 04 **Efficient ozone, sulfate, and ammonium free resist stripping process** [9256-40]
D. Dattilo, SUSS MicroTec Photomask Equipment GmbH & Co. KG (Germany); U. Dietze, SUSS MicroTec Inc. (United States)

9256 05 **Evaluation of AIMS D2DB simulation without calibration images** [9256-30]
M. Nishiguchi, K. Kanno, K. Hayano, H. Takamizawa, Dai Nippon Printing Co., Ltd. (Japan); K. Ohara, D. Son, V. Tolani, Luminescent Technologies, Inc. (United States)

WRITING TECHNOLOGIES

9256 06 **Challenges and technical requirements for multi-beam mask writer development** [9256-23]
S. H. Lee, J. Choi, H. J. Lee, I. K. Shin, S. Tamamushi, C.-U. Jeon, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)

9256 07 **EBM-9000: EB mask writer for product mask fabrication of 16nm half-pitch generation and beyond** [9256-5]
H. Takekoshi, T. Nakayama, K. Saito, H. Ando, H. Inoue, N. Nakayamada, T. Kamikubo, R. Nishimura, Y. Kojima, J. Yashima, A. Anpo, S. Nakazawa, T. Iijima, K. Ohtoshi, H. Anze, NuFlare Technology, Inc. (Japan); V. Katsap, S. Golladay, R. Kendall, NuFlare Technology, Inc. (United States)

9256 08 **High performance mask fabrication process for the next-generation mask production** [9256-21]
K. Yagawa, K. Ugajin, M. Suenaga, Y. Kobayashi, T. Motokawa, K. Hagihara, M. Saito, M. Itoh, Toshiba Corp. (Japan)

9256 09 **Characterization of decay component of resist surface charging on EBM-8000** [9256-41]
N. Nakayamada, T. Kamikubo, H. Anze, M. Ogasawara, NuFlare Technology, Inc. (Japan)

LITHOGRAPHY RELATED TECHNOLOGIES

9256 0A **Built-in lens mask lithography: challenge for high definition lens-less lithography** [9256-6]
N. Ueda, M. Sasago, A. Misaka, H. Kikuta, H. Kawata, Y. Hirai, Osaka Prefecture Univ. (Japan)

9256 0B **Study of the mask materials for PTD process and NTD process in practical ArF immersion lithography** [9256-34]
T. Adachi, A. Tani, K. Hayano, H. Takamizawa, Dai Nippon Printing Co., Ltd. (Japan)

FPD MASKS

9256 0C **Demands for masks in 1.5µm generation** [9256-3]
N. Izumi, M. Ando, Y. Nagai, N. Yabu, Canon Inc. (Japan)

METROLOGY

9256 0D **Novel CD-SEM measurement methodology for complex OPCed patterns** [9256-18]
H.-J. Lee, W. J. Park, S. H. Choi, D. H. Chung, I. Shin, B.-G. Kim, C.-U. Jeon, SAMSUNG Electronics Co., Ltd. (Korea, Republic of); H. Fukaya, Y. Ogiso, S. Shida, T. Nakamura, Advantest Corp. (Japan)

9256 0E **In-die registration measurement using novel model-based approach for advanced technology masks** [9256-38]
S. Sato, Toppan Printing Co., Ltd. (Japan); F. Laske, KLA-Tencor GmbH (Germany); S. Kunitani, T. Kamibayashi, A. Fuse, N. Takahashi, Toppan Printing Co., Ltd. (Japan); K.-D. Roeth, S. Czerkas, KLA-Tencor GmbH (Germany); M. Daneshpanah, KLA-Tencor Corp. (United States); Y. Nagaoka, KLA-Tencor Japan Ltd. (Japan)

9256 0F **Proximity corrected accurate in-die registration metrology** [9256-43]
M. Daneshpanah, KLA-Tencor Corp. (United States); F. Laske, KLA-Tencor GmbH (Germany); M. Wagner, KLA-Tencor Ltd. (Israel); K.-D. Roeth, S. Czerkas, KLA-Tencor GmbH (Germany); H. Yamaguchi, N. Fujii, S. Yoshikawa, K. Kanno, H. Takamizawa, Dai Nippon Printing Co., Ltd. (Japan)

9256 0G **Three dimensional profile measurement using multi-channel detector MVM-SEM** [9256-1]
M. Yoshikawa, S. Harada, K. Ito, T. Murakawa, S. Shida, J. Matsumoto, T. Nakamura, Advantest Corp. (Japan)

EUVL MASKS I

9256 0H **EUV mask process specifics and development challenges** [9256-8]
P. Nesladek, Advanced Mask Technology Ctr. GmbH Co. KG (Germany)

9256 0I **Ruthenium (Ru) peeling and predicting robustness of the capping layer using finite element method (FEM) modeling** [9256-28]
I.-Y. Jang, A. John, F. Goodwin, SEMATECH Inc. (United States); S.-Y. Lee, B.-G. Kim, S.-S. Kim, C.-U. Jeon, SAMSUNG Electronics Co., Ltd. (Korea, Republic of); J. H. Kim, Y. H. Jang, Yonsei Univ. (Korea, Republic of)

9256 0J **Extreme ultraviolet mask roughness: requirements, characterization, and modeling** [9256-37]
P. Naulleau, Lawrence Berkeley National Lab. (United States); S. Bhattaria, R. Chao, R. Claus, Univ. of California, Berkeley (United States); K. Goldberg, Lawrence Berkeley National Lab. (United States); F. Goodwin, SEMATECH Inc. (United States); E. Gullikson, Lawrence Berkeley National Lab. (United States); D. Lee, SAMSUNG Electronics Co., Ltd. (Korea, Republic of); A. Neureuther, Univ. of California, Berkeley (United States); J.-J.Park, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)

EUVL MASKS II

9256 0K **Learning from native defects on EUV mask blanks** [9256-42]
E. Gallagher, A. Wagner, M. Lawliss, G. McIntyre, IBM Corp. (United States); K. Seki, T. Isogawa, Toppan Photomasks, Inc. (United States); S. Nash, IBM Corp. (United States)

EUVL MASKS III

9256 0L **Towards reduced impact of EUV mask defectivity on wafer** [9256-33]
R. Jonckheere, D. Van den Heuvel, A. Pacco, I. Pollentier, B. Baudemprez, C. Jehoul, J. Hermans, E. Hendrickx, IMEC (Belgium)

9256 0M **EUV patterned mask inspection performance of an advanced projection electron microscope (PEM) system for hp 16 nm and beyond** [9256-22]
R. Hirano, S. Iida, T. Amano, T. Terasawa, H. Watanabe, EUVL Infrastructure Development Ctr., Inc. (Japan); M. Hatakeyama, T. Murakami, K. Terao, EBARA Corp. (Japan)

9256 0N **Screening EUV mask absorbers for defect repair** [9256-36]
T. Isogawa, K. Seki, Toppan Photomasks, Inc. (United States); M. Lawliss, E. Gallagher, IBM Corp. (United States); S. Akima, T. Konishi, Toppan Photomasks, Inc. (United States)

9256 0O **Defect analysis on actinic blank inspection tool** [9256-17]
T. Suzuki, H. Miyai, K. Takehisa, H. Kusunose, Lasertec Corp. (Japan); T. Yamane, H. Watanabe, I. Mori, EUVL Infrastructure Development Ctr., Inc. (Japan)

9256 0P **Performance in practical use of actinic EUVL mask blank inspection** [9256-9]
T. Yamane, Y. Kim, N. Takagi, T. Terasawa, EUVL Infrastructure Development Ctr., Inc. (Japan); T. Ino, T. Suzuki, H. Miyai, K. Takehisa, H. Kusunose, Lasertec Corp. (Japan)

EUV

9256 0Q **Etched multilayer mask in EUV lithography for 16 nm node and below** [9256-20]
G.-J. Kim, Hanyang Univ. (Korea, Republic of); M. Yeung, Fastlitho Inc. (United States); E. Barouch, Boston Univ. (United States); H.-K. Oh, Hanyang Univ. (Korea, Republic of)

9256 0R **Etched multilayer mask is better than conventional absorber mask** [9256-25]
G.-J. Kim, H.-K. Oh, I.-S. Kim, Hanyang Univ. (Korea, Republic of); M. Yeung, Fastlitho Inc. (United States); E. Barouch, Boston Univ. (United States)

9256 0S **Simulation of image placement error due to fabrication of black border on EUV mask** [9256-10]
Y. Nishiyama, S. Kondo, N. Fukugami, Toppan Printing Co., Ltd. (Japan)

9256 0T **Development of new inspection system with novel PEM for EUV pattern masks and its performance evaluation** [9256-26]
M. Hatakeyama, T. Murakami, K. Terao, K. Watanabe, Y. Tohma, EBARA Corp. (Japan); T. Amano, R. Hirano, S. Iida, T. Terasawa, H. Watanabe, EUVL Infrastructure Development Ctr., Inc. (Japan)

REPAIR

9256 0U **Application of EB repair for high durable MoSi PSM** [9256-29]
S. Kanamitsu, K. Morishita, T. Hirano, Toshiba Corp. (Japan)

EDA AND RET

9256 0V **Study of hotspot repair using cellular automata method** [9256-7]
N. Nagase, K. Takeuchi, M. Sakurai, T. Itoh, T. Okada, Fujitsu Semiconductor Ltd. (Japan)

9256 0W **Two new design methods for lithography mask: phase-shifting scattering bar and interlaced phase-shifting mask** [9256-2]
K.-T. Yeh, C.-Y. Huang, Winbond Electronics Corp. (Taiwan)

9256 0X **Use of ILT-based mask optimization for local printability enhancement** [9256-15]
A. Tritchkov, S. Kobelkov, S. Rodin, K. Sakajiri, E. Egorov, S.-S. Woo, Mentor Graphics Corp. (United States)

Author Index

Conference Committees

Symposium Chair

Toshiyuki Horiuchi, Tokyo Denki University (Japan)

Symposium Vice-chair

Masato Shibuya, Tokyo Polytechnic University (Japan)

Advisory Committee Chair

Masanori Komuro, New Energy and Industrial Technology Development Organization (Japan)

Advisory Committee

Morihisa Hoga, Dai Nippon Printing Company, Ltd. (Japan)
Masao Otaki
Tadahiro Takigawa
Yoshio Tanaka, Luminescent Technologies, Inc. (Japan)

Organizing Committee Chair

Toshiyuki Horiuchi, Tokyo Denki University (Japan)

Organizing Committee Vice-chair

Masato Shibuya, Tokyo Polytechnic University (Japan)

Organizing Committee

Uwe Behringer, UBC Microelectronics (Germany)
Parkson Chen, Taiwan Mask Corporation (Taiwan)
Han-ku Cho, Samsung Electronics Company, Ltd. (Korea, Republic of)
Junko Collins, SEMI Japan (Japan)
Brian J. Grenon, Advanced Technical Instruments (United States)
Takehiko Gunji, Sony Corporation (Japan)
Hideaki Hamada, HTL Company Japan Ltd. (Japan)
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)
Eiichi Hoshino, Nikon Corporation (Japan)
Kunihiro Hosono, Renesas Electronics Corporation (Japan)
Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)
Hideaki Mitsui, HOYA Corporation (Japan)
Warren Montgomery, CNSE (United States)
Ichiro Mori, EUVL Infrastructure Development Center, Inc. (Japan)
Hiroaki Morimoto, Toppan Printing Company, Ltd. (Japan)

Yoshiki Suzuki, KLA-Tencor Japan Ltd. (Japan)
Yoji Tonooka, Toppan Printing Company, Ltd. (Japan)
Koichiro Tsujita, Canon Inc. (Japan)
Anto Yasaka, Hitachi High-Tech Science Corporation (Japan)

Steering Committee Chair

Hiroaki Morimoto, Toppan Printing Company, Ltd. (Japan)

Steering Committee Vice-chairs

Kunihiro Hosono, Renesas Electronics Corporation (Japan)
Hidehiro Watanabe, EUVL Infrastructure Development Center, Inc. (Japan)

Steering Committee

Takayuki Abe, NuFlare Technology Inc. (Japan)
Akihiko Ando, Renesas Electronics Corporation (Japan)
Kazuko Jochi, KLA-Tencor Japan Ltd. (Japan)
Takashi Kamo, Toshiba Corporation Corporate Research and Development Center (Japan)
Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)
Yasutaka Morikawa, Dai Nippon Printing Company, Ltd. (Japan)
Teruaki Noguchi, JEOL Ltd. (Japan)
Yasushi Ohkubo, HOYA Corporation (Japan)
Tomoyuki Okada, Fujitsu Semiconductor Ltd. (Japan)
Kiwamu Takehisa, Lasertec Corporation (Japan)
Hiroyoshi Tanabe, Intel K.K. (Japan)
Nobuyuki Yoshioka, Dai Nippon Printing Company, Ltd. (Japan)

Program Committee Chair

Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)

Program Committee Vice-chairs

Akihiko Ando, Renesas Electronics Corporation (Japan)
Nobuyuki Yoshioka, Dai Nippon Printing Company, Ltd. (Japan)

Program Committee

Tsukasa Abe, Dai Nippon Printing Company, Ltd. (Japan)
Jeff Farnsworth, Intel Corporation Technology and Manufacturing Group (United States)
Thomas B. Faure, IBM Corporation (United States)
Kazuyuki Hagiwara, D2S, K.K. (Japan)
Shigeru Hirukawa, Nikon Corporation (Japan)
Koji Hosono, Fujitsu Semiconductor Ltd. (Japan)
Hidemichi Imai, Dai Nippon Printing Company, Ltd. (Japan)

Ichiro Kagami, Sony Semiconductor Corporation (Japan)
Franklin Kalk, Toppan Photomasks, Inc. (United States)
Byung-Gook Kim, Samsung Electronics Company, Ltd. (Korea, Republic of)
Yutaka Kodera, Toppan Printing Company, Ltd. (Japan)
Jun Kotani, Toppan Printing Company, Ltd. (Japan)
John Lin, Taiwan Semiconductor Manufacturing Company (Taiwan)
Mark Ma, Photronics, Inc. (United States)
Junji Miyazaki, ASML Japan Company, Ltd. (Japan)
Koji Murano, TOSHIBA Corporation (Japan)
Yoshinori Nagaoka, KLA-Tencor Japan Ltd. (Japan)
Yasutoshi Nakagawa, JEOL Ltd. (Japan)
Noriaki Nakayamada, NuFlare Technology Inc. (Japan)
Naoki Nishida, HOYA Corporation (Japan)
Yuji Nonami, Panasonic Corporation (Japan)
Steffen Schulze, Mentor Graphics Corporation (United States)
Yasunari Sohda, Hitachi, Ltd. (Japan)
Osamu Suga, EUVL Infrastructure Development Center, Inc. (Japan)
Yasuko Tabata, TowerJazz Panasonic Semiconductor, Ltd. (Japan)
Yoji Takagi, Applied Materials Japan, Inc. (Japan)
Kiwamu Takehisa, Lasertec Corporation (Japan)
Richard Tseng, Taiwan Mask Corporation (Taiwan)
Yoichi Usui, HOYA Corporation (Japan)
Nobuhiko Yabu, Canon Inc. (Japan)
Tetsuya Yamamoto, KLA-Tencor Corporation (United States)

Session Chairs

1 Opening Session
Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)

2 Inspection and Cleaning
Akihiko Ando, Renesas Electronics Corporation (Japan)
Hidemichi Imai, Dai Nippon Printing Company, Ltd. (Japan)

3 NIL
Jun Kotani, Toppan Printing Company, Ltd. (Japan)

4 Writing Technologies
Uwe Behringer, UBC Microelectronics (Germany)
Noriaki Nakayamada, NuFlare Technology, Inc. (Japan)

5 Lithography Related Technologies
Nobuyuki Yoshioka, Dai Nippon Printing Company, Ltd. (Japan)

6 FPD Masks
Ichiro Kagami, Sony Semiconductor Corporation (Japan)
Nobuhiko Yabu, Canon Inc. (Japan)

8 Invited Session
Thomas Faure, IBM Corporation (United States)
Yoshinori Nagaoka, KLA-Tencor Japan Ltd. (Japan)

9 Metrology
Thomas Faure, IBM Corporation (USA)
Yoshinori Nagaoka, KLA-Tencor Japan Ltd. (Japan)

10 EUVL Masks I
Natalia Davydova, ASML Netherlands B. V. (The Netherlands)
Tsukasa Abe, Dai Nippon Printing Company, Ltd. (Japan)

11 EUVL Masks II
Jeff Farnsworth, Intel Corporation (United States)
Koji Murano, Toshiba Corporation (Japan)

12 EUVL Masks III
Byung-Gook Kim, Samsung Electronics (Korea, Republic of)
Yutaka Kodera, Toppan Printing Company, Ltd. (Japan)